

Highlights

- Increased sensitivity for 0 - 1000 ppb of Hydrogen in air
- Response time ($t_{60} < 1$ sec)
- Low cost production
- Reduced power consumption and improved portability through miniaturization

Sensor design and Fabrication

Sensors developed in this work are based on the LAMTEC's state of the art CarboSen sensor design [1] a planar type solid state mixed potential electrochemical sensor.

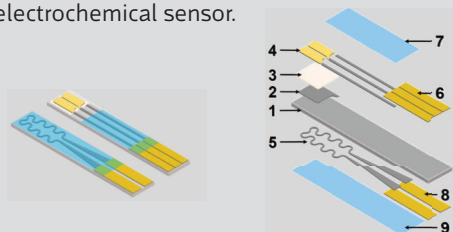


Fig. 1: Schematic view of the state of the art CarboSen sensor design, 1: carrier substrate, 2: reference electrode, 3: YSZ, 4: Working electrodes, 5: heating element, 6: electrode contact pads, 7: glass layer, 8: heating element contact pads and 9 glass layer.

Functional materials and surface morphology corresponding to the electrode 1 and 2 were experimentally optimized based on an extensive test matrix. In total 75 different sensor types were fabricated using a combination of screen printing technology and Physical Vapor Deposition (PVD).

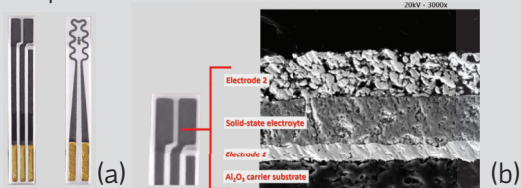


Fig. 2: (a) Fully fabricated LHyCon sensor. (b) Cross section SEM image of a specific location on the fabricated sensor.

Sensor Performance

10 sensors from each of the fabricated sensor types were tested using various low concentrations of hydrogen in air mixtures and different sensor operating temperatures.

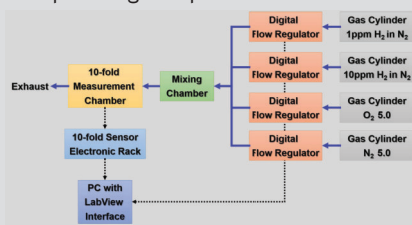


Fig. 3: Test gas measurement setup

All sensor types were tested with three concentration ranges:

- 0 - 1000 ppb of hydrogen in air
- 1 - 7 ppm of hydrogen in air
- 7 - 100 ppm of hydrogen in air

A measurement procedure was followed uniformly for all the sensors measured in the project.

The measured results were analyzed and it was concluded that the sensor type LH44 best fulfilled the defined goals of the LHyCon project. LH44 sensor type shows an increased Hydrogen sensitivity compared to the state of the art CarboSen sensor. It also delivers a nearly linear sensor signal behavior corresponding to the increasing hydrogen concentration between 0 ppm and 7 ppm hydrogen in air.

[1] <https://www.lamtec.de/produkte/sensorik/hydrogen-h2.html>

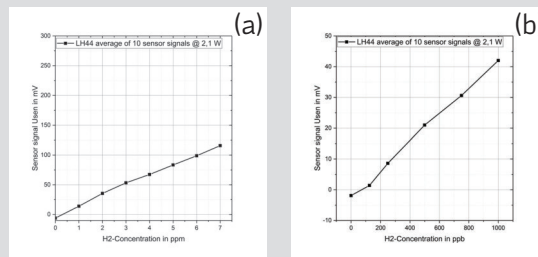


Fig. 4: Sensor signal characteristic of LH44 sensor type when exposed with (a) 0 - 7 ppm of hydrogen in air and (b) 0 - 1000 ppb of hydrogen in air.

Miniaturized Sensor

A 3 X 3 mm² miniaturized sensor version of the LH44 sensor was designed and fabricated. It is named as LH44X3. The exploded schematic view of the miniaturized LH44X3 sensors is shown below.

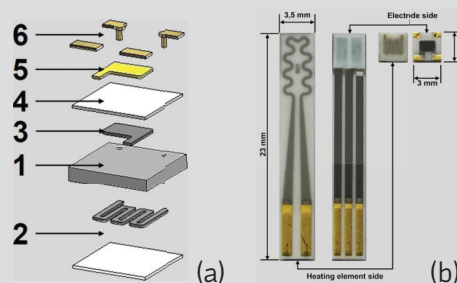


Fig. 5: (a) Exploded schematic representation of miniaturized LH44X3 sensors. (b) Picture comparing the fully fabricated LH44 sensor in the standard size sensor and the LH44X3 miniaturized sensor

The design simulation of the heating element was done using SolidWorks 2018 and it was optimized in such a way that the minimum heating required to achieve the optimum sensor temperature was in the range of 0,8 - 1 W

A fully fabricated LH44X3 assembled in a Transistor Outline (TO) housing is shown in the following picture.

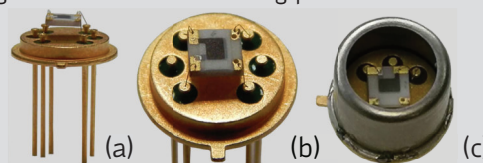


Fig. 6: A fully fabricated LH44X3 and assembled in a TO housing. (a) side view, (b) top view and (c) top view with full TO housing of the LH44X3 sensors.

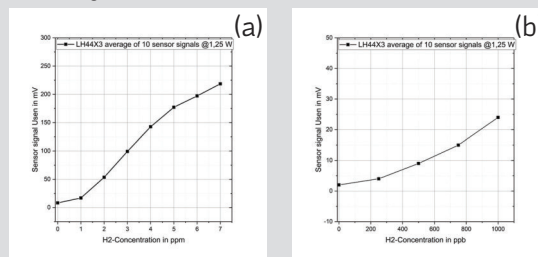


Fig. 7: Sensor signal characteristic of LH44X3 sensors when exposed with 0 - 1000 ppb of hydrogen in air. The miniaturized sensor LH44X3 shows an optimal functionality and a very high sensitivity for the measurement of low hydrogen concentrations in air.

Acknowledgement

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